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The Whiting
Gadus merlangus L.
in the North Sea

By R. W. ELLIS, B.Sc. & R. JONES, B.Sc.

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The Whiting *(Gadus merlangus* L.) in the North Sea

INTRODUCTION

The literature on whiting biology is not extensive. Among the earlier authors useful contributions the distribution and general biology of the whiting in the North Sea have been given by Heincke 905), Damas (1909), Ehrenbaum (1909) and Schmidt (1909). The distribution of the whiting based commercial trawler landings has been described by D'Arcy Thompson (1910), Borley and Thursby-lham (1926) and Willer (1951); Poulsen (1937), Blegvad (1946), Knudsen (1950) and Jensen (1952) ve given accounts of the whiting in Danish waters, while Saemundsson (1925) has contributed to our owledge of whiting in Icelandic waters and more recently Desbrosses (1945 and 1948) has described e distribution and biology of whiting off the French Atlantic coast. Relevant statistics are given in e *"Bulletin Statistique"* of the International Council for the Exploration of the Sea.

The commercial statistics of European countries (Appendix I) show that the whiting (*Gadus merngus*, L.) is distributed over most of the fishing grounds of the north-eastern Atlantic. The greatest tches of marketable fish are taken in the North Sea and, during the period 1928-1938, 53% of the entire uropean catch of whiting came from this area alone. The importance of the North Sea to the whiting hery became even more marked after the war and about 70% of the European catch came from this urce in 1951 and 1952. Second in importance to the North Sea in the ten years before the war was the nglish Channel, which from 1928-1938 contributed about 13% of the total European landings of adult hiting. After the war the Irish Sea and Bristol Channel took second place and contributed 12% of the tal landings. This, however, is not the complete picture, since these figures take no account of the anish "Industrifisk" fishery, whose products are used primarily for fish meal. This fishery, in which ry small meshed nets are used, is principally for young herring and sprats and has tended to increase nsiderably since the war. Accounts of the fishery are given by Blegvad (1946), Knudsen (1950) and nsen (1952). Details of the quantities of immature whiting thus caught incidentally (combined with the latively insignificant landings of adult whiting) up to 1948 are given in Table I. It has recently been timated from Danish fishery statistics* that about 44 million kilos (44,000 metric tons) of such small

TABLE I

Landings in millions of kilos of whiting from all Danish waters in the years 1925-48. (From Knudsen, 1950).

1925	0·19	1931	0·97	1937	4·02	1943	11·40
26	0·08	32	1·24	38	4·35	44	7·40
27	0·12	33	1·69	39	7·50	45	9·50
28	0·31	34	2·23	40	5·50	46	5·70
29	0·55	35	2·78	41	6·00	47	11·40
30	0·58	36	3·78	42	8·90	48	18·30

These figures include landings of both immature fish as well as adult food fish. Comparison with Appendix II shows that from 1930 onwards adult food fish made up a very small proportion of these totals.

hiting were landed from this fishery in 1952: a figure that is more than half of the total of 73 million kilos 3,000 metric tons) of whiting landed in that year in Europe for human consumption from the whole the North Sea! There are reasons, however, for believing that this is a considerable overestimate—rhaps the total is nearer 20 million kilos (20,000 metric tons). On the other hand, the whole industrial hery is still increasing. Other landings of whiting not taken into account in the *"Bulletin Statistique"* e associated with the trawl fishery for herring; the trawls used in this fishery have meshes below the ze legally permissible in white-fish trawls. It has been estimated very roughly, from analyses of landings

**Fiskeriberetningen for °ret 1952*

of herring trawlers, that about 15 million kilos (15,000 metric tons) of mainly small whiting have be captured annually by this method within the North Sea during post-war years.

The whiting landed from the North Sea are caught by vessels from eight countries among whi the United Kingdom (England and Scotland) is responsible for more than half of the landings (Append II). Up to 1929, English landings constituted more than half of these and before the Great War were nea twice as large as the Scottish landings; but Scottish landings predominated from 1930 onwards, un by 1952 Scotland was landing 6-7 times as much whiting as England (Fig. 1) and about half of the wh

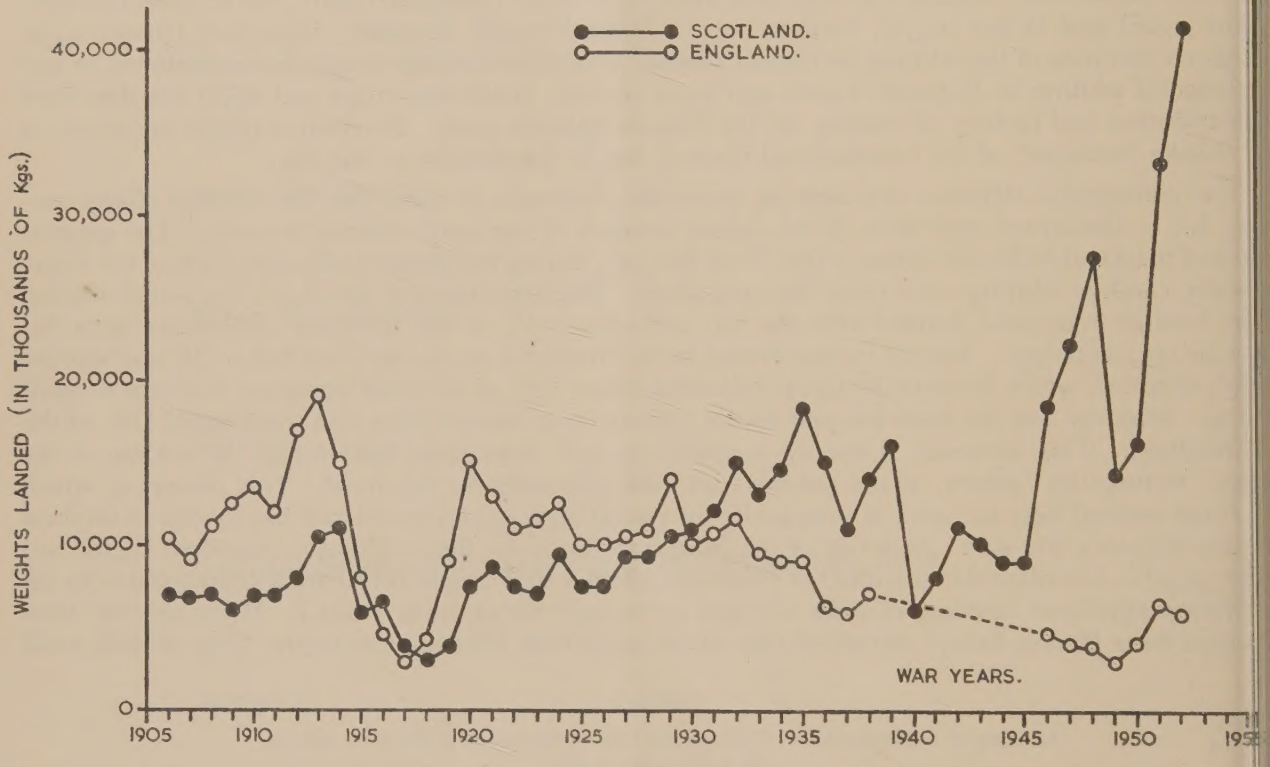


Fig. 1 Total landings of whiting from the North Sea in England and Scotland (from *Bulletins Statistiques des Pêches Maritimes*).

North Sea catch. Much of this increase in the Scottish landings of whiting was due to the growth of t seine net fishery (Table II) which by 1953 was contributing more than a third of the Scottish whiti total: a remarkable growth in importance since 1921 when this method of fishing was introduced Scotland. By 1952, over 50% of the North Sea whiting were landed in Scotland and, although n commanding so high a price as cod or haddock, the whiting now ranks third in importance by weig and value amongst the fish landed in Scotland. Second in importance to the United Kingdom is Fra which now contributes 20-30 % of the North Sea total of whiting, while Belgium and Holland contrib the greater proportion of the remaining landings of fish for direct human consumption.

DISTRIBUTION OF O AND I GROUP WHITING IN THE NORTHERN NORTH SEA

Eggs and larvae have been encountered in the northern North Sea as far east as the Norwegi Deep (Saville, 1950), on the Dogger Bank (Heincke, 1905) and in the Southern Bight (Simpson, 194

According to data collected by Scottish research ships during the spawning months of 1949-19 (Table III), whiting in the northern North Sea were then spawning principally in April and May. Furth

TABLE II

Whiting Landings in Scotland in oo's cwt.

Year	Trawl	Nets other than trawls	All line methods	Total all vessels
1911	1,266	—	155	1,421
1912	1,548	0·04	192	1,740
1913	2,103	1	133	2,237
1914	2,081	—	167	2,249
1915	794	0·2	331	1,126
1916	781	0·01	286	1,067
1917	375	0·07	225	599
1918	466	1	281	749
1919	566	0·06	276	842
1920	1,369	0·1	210	1,579
1921	1,417	0·4	363	1,781
1922	1,312	3	343	1,658
1923	1,282	10	243	1,535
1924	1,894	14	128	2,037
1925	1,502	11	142	1,654
1926	1,476	11	189	1,677
1927	1,847	21	212	2,081
1928	1,870	29	201	2,100
1929	2,332	27	130	2,488
1930	2,325	23	154	2,502
1931	2,552	35	239	2,826
1932	3,032	84	261	3,377
1933	2,423	222	172	2,816
1934	2,525	419	225	3,168
1935	3,283	639	176	3,897
1936	2,781	459	119	3,359
1937	2,022	499	103	2,625
1938	2,455	639	170	3,264
1939	2,835	116	641	3,592
1940	1,093	772	64	1,951
1941	752	1,387	140	2,232
1942	969	2,421	96	3,562
1943	835	1,903	31	2,805
1944	789	1,674	10	2,509
1945	841	1,555	9	2,412
1946	1,835	2,503	20	4,395
1947	3,196	2,832	22	6,100
1948	3,837	2,824	8	6,771
1949	2,227	2,010	8	4,245
1950	2,393	2,154	10	4,557
1951	3,803	3,087	25	6,989
1952	4,977	3,181	23	8,181
1953	4,129	2,922	25	7,076

TABLE III

Showing female whiting maturities from "Explorer" and "Scotia" catches 1949-51.

	Feb./March		April		May		June	
	No.	% at each stage of Maturity	No.	% at each stage of Maturity	No.	% at each stage of Maturity	No.	% at each stage of Maturity
Fish one year old in April of preceding year								
Immature	58	7·0	10	6·3	144	36·0	—	—
Maturing	766	92·2	42	26·6	22	5·5	—	—
Ripe	5	0·6	69	43·7	157	39·3	—	—
Ripe Running ..	2	0·2	33	20·9	4	1·0	—	—
Spent	—	—	4	2·5	73	18·2	17	100·0
Fish two years old in April of preceding year								
Immature ..	5	0·9	—	—	3	2·0	—	—
Maturing ..	526	96·2	6	4·2	3	2·0	—	—
Ripe	11	2·0	92	64·8	94	63·1	—	—
Ripe Running ..	5	0·9	44	31·0	48	32·2	—	—
Spent	—	—	—	—	1	0·7	22	100·0
Fish three years old in April of preceding year								
Immature ..	1	0·4	—	—	—	—	—	—
Maturing	222	87·0	12	9·1	—	—	—	—
Ripe	30	11·8	64	48·5	30	62·5	—	—
Ripe Running ..	2	0·8	54	40·9	1	2·0	—	—
Spent	—	—	2	1·5	17	35·5	20	100·0

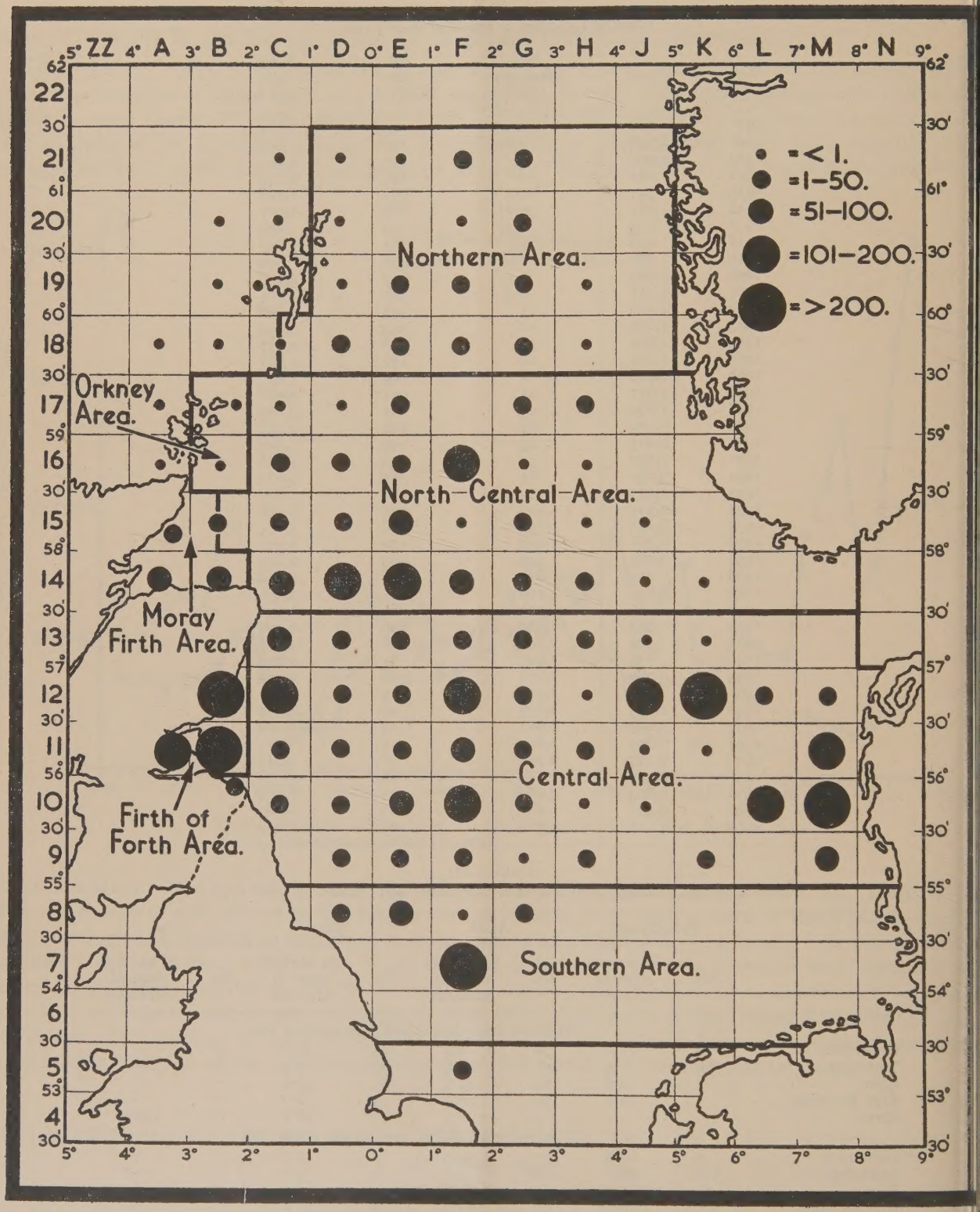

5° ZZ 4° A 3° B 2° C 1° D 0° E 1° F 2° G 3° H 4° J 5° K 6° L 7° M 8° N 9°
62° 30' 61° 30' 60° 30' 59° 30' 58° 30' 57° 30' 56° 30' 55° 30' 54° 30' 53° 30'
22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4
= < 1.
= 1–50.
= 51–100.
= 101–200.
= > 200.
Northern Area.
Orkney Area.
North Central Area.
Moray Firth Area.
Central Area.
Firth of Forth Area.
Southern Area.
5° 4° 3° 2° 1° 0° 1° 2° 3° 4° 5° 6° 7° 8° 9°

Fig. 2 Numbers of 0 brood of whiting per hour's fishing by F.R.S. *Explorer*. Mean 1932–1939, and 1946–1951 (July–Dec.).

south spawning tends to be earlier, often even in January (Simpson, 1948), and it is considered that temperature is an important factor contributing to the time of spawning (Desbrosses, 1945). It is difficult to assess the duration of the pelagic phase. Heincke (1905) stated that this continues until the fish is about 50 mm (2 inches) in length and that the whiting probably has a considerably longer pelagic life than that of cod or haddock. Whiting are normally first caught on the bottom at a size of about 60 mm but, even when the bottom habit has been assumed, young whiting tend to return to the surface periodically (Heincke, 1905). Also, occasional catching of adults in drift nets suggests that even the adults are not exclusively demersal in habit. After hatching, young whiting often associate with the jellyfish *Cyanea capillata*, swimming amongst the tentacles without apparent harm (Heincke, 1905; Ehrenbaum, 1909; Damas, 1909; and Desbrosses, 1945). Recent information from Mr. A. Saville of this laboratory (unpublished) suggests that the whiting larvae in the northern North Sea associate with Cyanea, not immediately after hatching, but at about the 20 mm stage, in June, when the medusae are plentiful.

O group whiting first appear in "Explorer's" trawl hauls (small mesh cover) about the middle of July, at a minimum size of about 60 mm. The catches of whiting in their first year of life are plotted in Fig. 2 for each statistical square and are tabulated in Table IV on a regional basis. The extents of the regions included in Table IV are given in Fig. 2, which shows clearly that o group whiting were most densely distributed between latitudes 55° and 58°N, from the Firth of Forth to the Danish coast. In this respect the distribution of young whiting differs from that of young haddock, which are usually scarce east of longitudes 3° or 4° east (Thompson, 1930). The greatest catches per unit fishing time by "Explorer" were taken in the Firth of Forth (Table IV) and extensive inshore sampling by "Kathleen" in 1938, 1939, 1947, 1948 and 1949 showed that in the Forth estuary the majority of the o group were caught in depths from 7–37 metres.

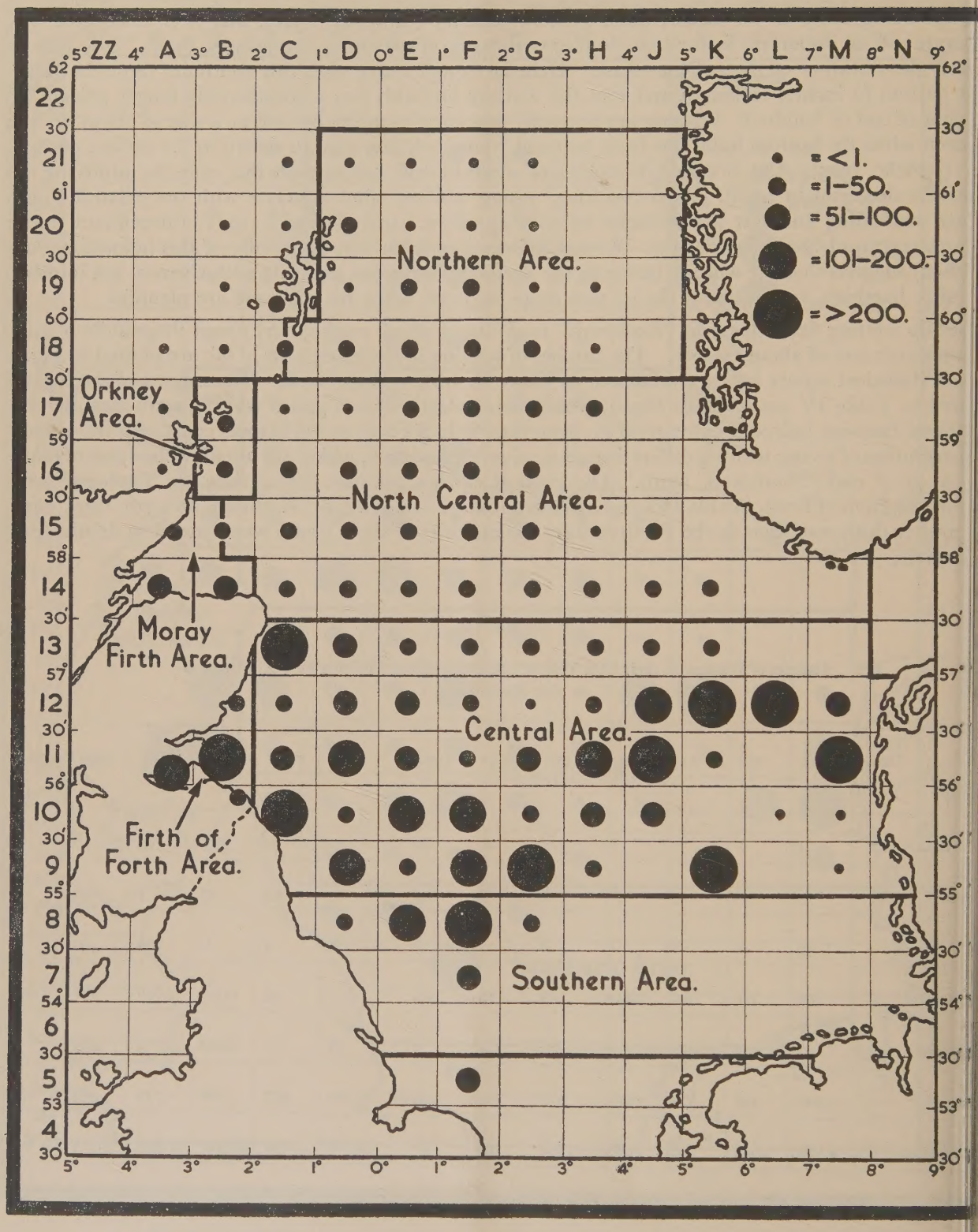
TABLE IV

Catches of Whiting in their First Year of Life per 10 Hours' Fishing by F.R.S. *Explorer*
July–December

Year Classes / North Sea Areas	1932	1933	1934	1935	1936	1937	1938	1946	1947	1948	1949	1950	1951
North Western ..	4	+	+	3	15	+	20	+	+	2	3	6	+
Northern ..	73	90	10	16	18	10	51	+	43	23	7	136	+
Skagerrak	45	+	5	+	8	+	+	+	5	+	294	+	+
North Central ..	100	120	342	2,604	23	201	429	25	53	1,002	1,046	271	1,671
Moray Firth ..	93	233	200	+	66	157	2	36	+	2,436	124	579	9
Central	1,001	495	654	1,510	382	15	75	200	437	266	1,777	400	271
Firth of Forth ..	4,364	3,646	720	7,089	1,286	136	+	2,100	250	10,320	1,936	3,114	605

+ = less than 0·5 fish per 10 hours' fishing.

The distribution of 1 group whiting (Table V and Fig. 3) is much the same as the o group, the main concentration in this instance being between latitudes 55° and 57°N.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62° 22 30' 21 61° 20 30' 19 60° 18 30' 17 59° 16 30' 15 58° 14 30' 13 57° 12 30' 11 56° 10 30' 9 55° 8 30' 7 54° 6 30' 5 53° 4 30'
= <1.
= 1–50.
= 51–100.
= 101–200.
= >200.
Northern Area.
Orkney Area.
North Central Area.
Moray Firth Area.
Central Area.
Firth of Forth Area.
Southern Area.

Fig. 3 Numbers of 1 brood whiting per hour's fishing by F.R.S. *Explorer*. Mean 1932–1939, and 1946–1951.

The effect of infection by the copepod parasite *Lernaeocera branchialis*, L. on the distribution and migration habits of young whiting has been studied by Sproston and Hartley (1941) in the Plymouth area. They found that, soon after taking to the bottom in early summer, the 0 group whiting come inshore where the intermediate host of the parasite (the flounder) is to be found. In the following summer, when the uninfected whiting migrate offshore, the infected whiting still linger inshore. From the limited information available it appears that Lernaeocera may have a similar effect in Scottish waters.

TABLE V

Catches of Whiting in their Second Year of Life per 10 Hours' Fishing by F.R.S. *Explorer* Annually

North Sea Areas \ Year Classes	1931	1932	1933	1934	1935	1936	1937	1938	1945	1946	1947	1948	1949	1950
North Western	231	9	+	3	84	1	+	+	1	+	17	+	139	40
Northern	116	76	+	10	63	3	2	+	8	1	15	14	205	+
Orkney	1,162	264	47	13	406	19	+	+	5	3	2	83	5	111
North Central	581	225	69	146	440	228	95	20	120	10	75	224	320	355
Moray Firth	3,505	424	79	89	306	70	37	58	2,235	+	12	346	113	90
Central	5,166	1,629	548	1,085	1,904	1,708	251	20	944	83	566	526	1,878	586
Firth of Forth	9,383	1,822	654	124	1,058	73	+	85	3,286	647	51	133	1,127	146

+ = less than 0·5 fish per 10 hours' fishing.

ADULT DISTRIBUTION WITHIN THE NORTH SEA

Adult whiting are found all over the North Sea. From a study of commercial trawling statistics, was concluded by D'Arcy Thompson (1910) and Borley and Thursby-Pelham (1926) that the greatest ensities of whiting were to be found in the northern North Sea while the smallest numbers were in the uth and east. Ehrenbaum (1909) on the other hand, from a consideration of earlier statistics, stated at the whiting reaches its greatest density in the southern North Sea. Discrepancies of this nature, owever, are as likely to be due to changes in the quantities of fish rejected at sea as to a real change in e distribution of a species, although the possibility of a real change in distribution must be allowed for. ore recent evidence relating to the distribution of the adult whiting has been collected from an exam- ation of landings by British steam trawlers, Aberdeen trawlers and research vessels.

The landings per 100 hours fishing from each statistical square by British steam trawlers during e period 1932-1939 are shown in Fig. 4. In so far as these statistics are indicative of abundance, the eatest density of whiting is in the northern North Sea. A similar conclusion is to be drawn from the berdeen trawler landings, although the difference between north and south was less marked. The eights of whiting landed per unit of fishing effort by Aberdeen trawlers from the northern, middle, east ast and south-eastern grounds were approximately in the ratios of 15 : 13 : 6 : 5. The boundaries of these eas are shown on Fig. 4. The Aberdeen trawler statistics revealed a tendency not only towards landing

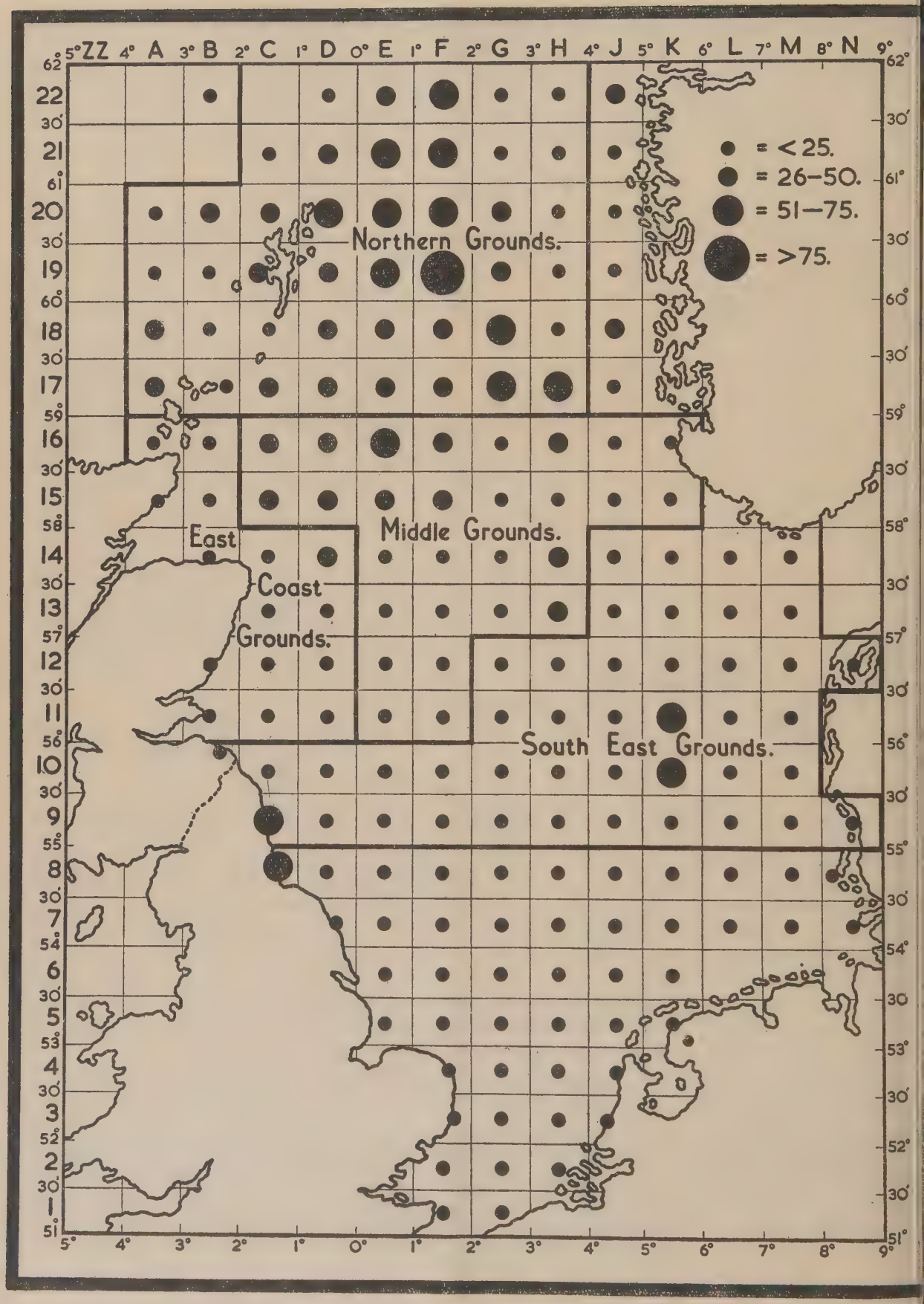

Fig. 4 Weights of whiting in cwt per 100 hour's fishing by British Steam trawlers. Weighted means 1932–1939.

more whiting from the northern North Sea than elsewhere but also towards the landing of a disproportionately large number of large whiting from that region, as is shown in Fig. 5.

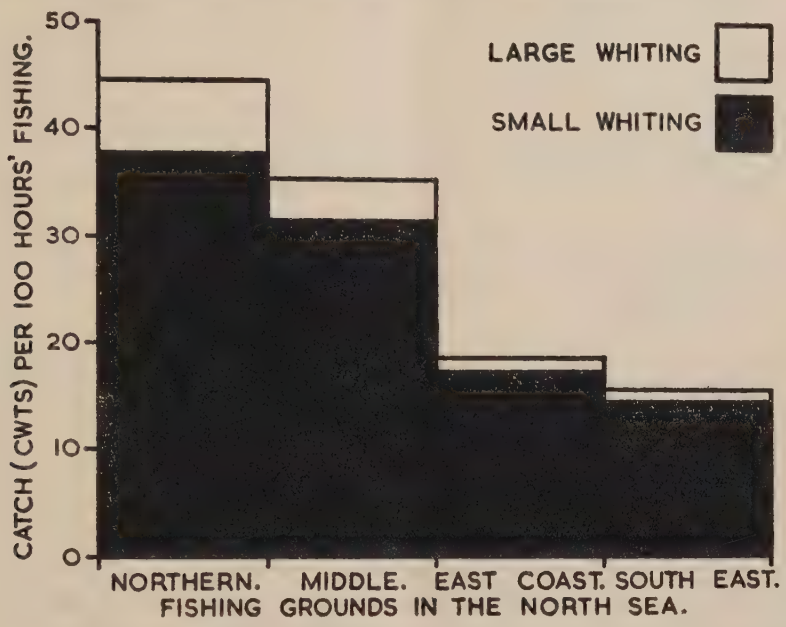

Fig. 5 Landings of large and small whitings by Aberdeen trawlers from the North Sea (1930–1939).

These data certainly appear to support the conclusion of D'Arcy Thompson (1910) that whiting are most dense in the northern North Sea, but it is important that the limitations of these statistics are appreciated. For example, in the case of the British trawler landings, those from the north are principally by Scottish trawlers using round fish trawls and those from the south by English, using for the most part flat fish trawls. That there is a difference in the relative efficiences of the gears used by these vessels in catching whiting has been demonstrated by Margetts (1949) and Parrish (1949b); both writers showed that under comparable conditions the Scottish roundfish trawl caught many more whiting than the English flatfish trawl. Much of the difference found by D'Arcy Thompson may have been due to the types of nets used. The Aberdeen trawler statistics are not open to this objection and they show that more whiting are landed per unit fishing time from the north than from the south. In this instance, however, as one might expect, the difference in amounts landed between north and south is much less conspicuous.

With respect to the available research ship information, the catches of whiting of two years and older, per hour's fishing time by F.R.S. *Explorer* in the northern and central North Sea, have been tabulated for each year and each statistical square in which fishing has taken place. The mean catches for each row and column of squares are shown in Table VI.

TABLE VI

Showing for the years 1932-1938 the mean catches of two year and older whiting by *Explorer* in each row and column of statistical squares in the North Sea.

Row	9	10	11	12	13	14	15	16	17	18	19	20	21
Catch/hr.	61·5	64·9	64·9	62·5	88·1	62·4	56·6	43·7	36·2	34·5	60·1	26·6	20·6
Column	A	B	C	D	E	F	G	H					
Catch/hr.	19·2	52·7	80·9	65·8	45·1	75·9	39·0	56·5					

In this sampling, the maximum numbers per hour's fishing were taken in square C.13. An analys of variance of the logarithms of the mean catches, corresponding to those in Table VI, for each ye separately was made and it was found that:

(*a*) Significantly higher catches per unit time were recorded in the years 1932-1934 than in tl years 1935-38.

(*b*) The differences between the row means were not significant at the 5% level (i.e., there were n significant north-south differences in the catches).

(*c*) There were significant differences between the column means even when column A was exclud from the analysis.

It must be concluded, therefore, that the individual research ship data, perhaps owing to the hig year to year variation in catches, are not adequate for confirming the distribution picture of adult whiti as presented by commercial records.

Furthermore, Jones (1955b) has shown that *Explorer* does not catch as high proportions of large fi as the average commercial vessel. There is, therefore, justification for regarding the data derived fro the catches of commercial vessels as being the more reliable for determining the distribution of the adu whiting. Accordingly, since the one year old whiting are largely concentrated between latitudes 5 and 57°N (p. 7), the available evidence is not inconsistent with the conception that the centre of densi of the older whiting is no longer between those latitudes, but rather farther to the north.

It is interesting to consider whether this apparent northerly drift in the centre of the density whiting of two years and over is due to a real migration, or simply to the fact that the overall fishi effort in the central North Sea, as judged from British trawler statistics alone, happens to be two or thr times as great as that further north. It is fairly obvious that, unless the mixing of whiting from the nor and central North Sea happened to be exceptionally great, the effect of the relatively high rate of fishi in the central and southern areas would be to deplete stocks there at a greater rate than elsewhere. Th then, could easily lead to an apparent northerly shift in the centre of density, although from causes oth than that of direct migration (Ellis, 1950). So far there has been little or no success in tagging whiti and, in the absence of tagging records, it is indeed difficult to determine whether the more northe distribution arises from active migration or from the effects of differences in fishing effort. A simi northerly shift in density is clearly shown by certain haddock statistics (Thompson, 1929, Jones and M. 1951-1954), and in this species also it is difficult to say what part differential fishing mortality may ha contributed to the phenomenon.

BROOD FLUCTUATIONS

The average catches taken by *Explorer* per 10 hours' fishing of whiting in their first and second ye of life are shown for the pre- and post-war years in Tables IV and V respectively. As in the case of t haddock (Parrish, 1949a), it appears that the 0 group were not completely represented in *Explore* trawl, since the numbers caught were frequently less than those of the 1 group in the following ye For this reason it is probable that the second year (1 group) frequencies give a more reliable estimate relative brood strength and potential recruits to the commercial fishery than does the 0 brood. In or to arrive at a figure for each year, the numbers per unit fishing time from each area were weighted proportion to the areas of the regions concerned. The "weights" that were actually used are shown Table VII.

TABLE VII

Northern North Sea Regions and their Areas.

Region	Area (00's of sq. miles)
Northern	189
Orkney	18
North Central	288
Moray Firth	18
Central	450
Firth of Forth	13

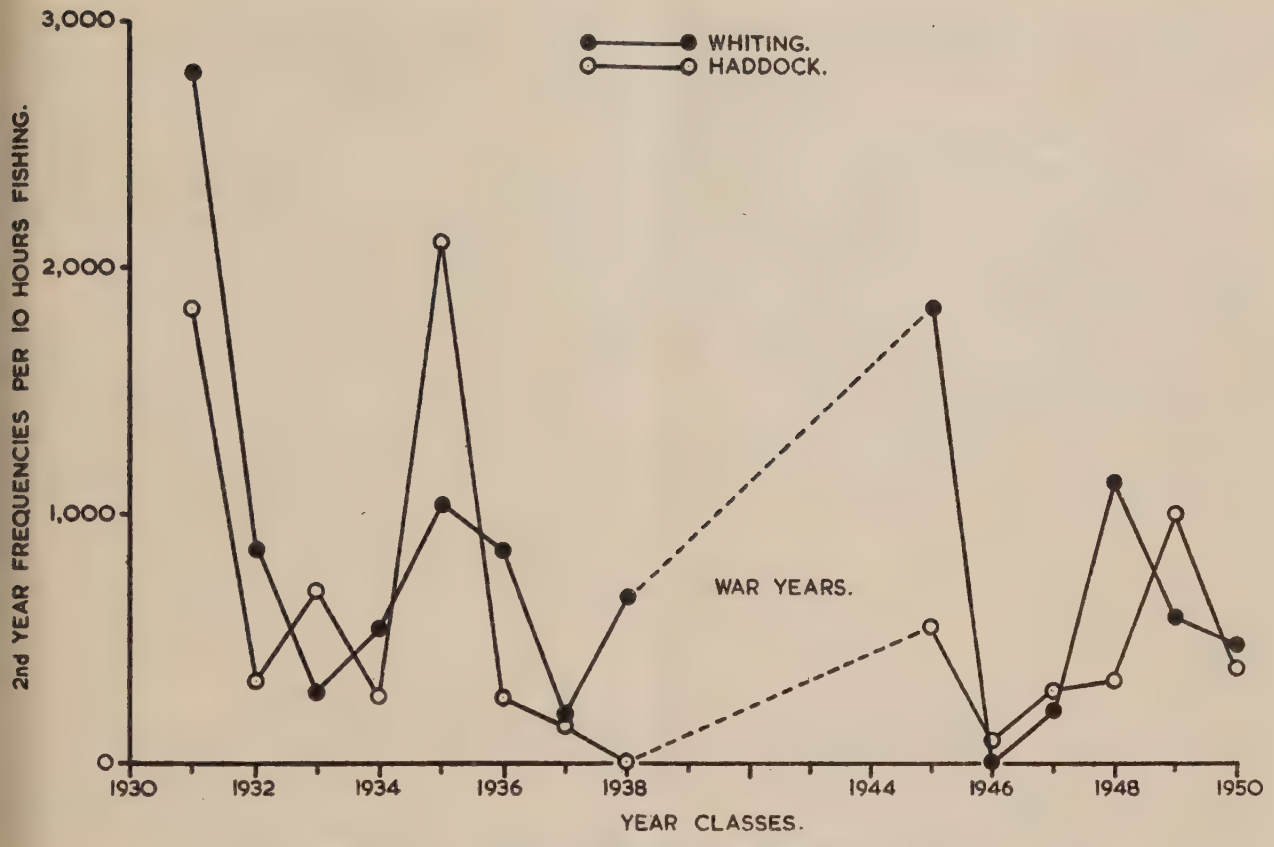

Fig. 6 Fluctuations in year class strengths of North Sea haddock and whiting.

These were used in estimates of brood strengths, as plotted in Fig. 6 along with the comparable haddock figures up to 1945 (Parrish 1949a and afterwards from more recent data). There is some agreement between the two graphs. The years 1931, 1935, 1945 and 1948 were particularly good for whiting.

GROWTH

The growth of whiting in North Sea waters has been studied by Fulton (1901), Damas (1909) and Desbrosses (1948). Since 1946, material has been collected by F.R.S. *Explorer* from the northern and eastern parts of the North Sea as well as from the Moray Firth and Orkney areas. This has been analysed by grouping successive years in pairs and then determining for each brood on each sampling occasion,

(*a*) its original mean length (year **x**), and

(*b*) the annual increment in mean length obtained in the following year (year x+1).

The annual increments obtained in this manner were then plotted against the corresponding original lengths, giving a relationship between annual growth and size. This was done for each area and period separately and in each case it was found that the relationship could be satisfactorily fitted by a straight line. Straight lines were fitted to the data by the method of least squares and analysis showed that for each area-period (1947-1948, 1948-1949 and 1949-1950) there was no significance in the differences between the slopes and intercepts. All the data were therefore pooled to give one relationship between annual increment (I) and length (L). This was:

$$I = 14{\cdot}06 - 0{\cdot}318L$$

The asymptotic length towards which this calculated growth curve tends can be determined from this equation as that value of L for which the annual increment (I)=O.

$$\text{i.e. when } I=O,\ L=\frac{14{\cdot}06}{0{\cdot}318}=44{\cdot}2 \text{ cm.}$$

Further details for determining the form of a complete growth curve from such an increment/leng relationship is described elsewhere (Jones 1955c). The final equation is

$$L=44{\cdot}2\ (1-e^{-0{\cdot}383(t-t_o)})$$

where L is the mean length of a year class aged t years.

The parameter t_o is the age at which the mean length is zero. In practice this is also zero, but sin the theoretical curve has been fitted to data extending from ages one to six, extrapolation need n necessarily cause it to go through the origin. Therefore, t_o must be chosen to make the theoretic curve go through some fixed point and this has been done to comply with the fact that the one-year-o whiting were approximately 17 cm long. The final curve then becomes:

$$L=44{\cdot}2\ (1-e^{-0{\cdot}383(t+0{\cdot}44)})$$

and is plotted in Fig. 7.

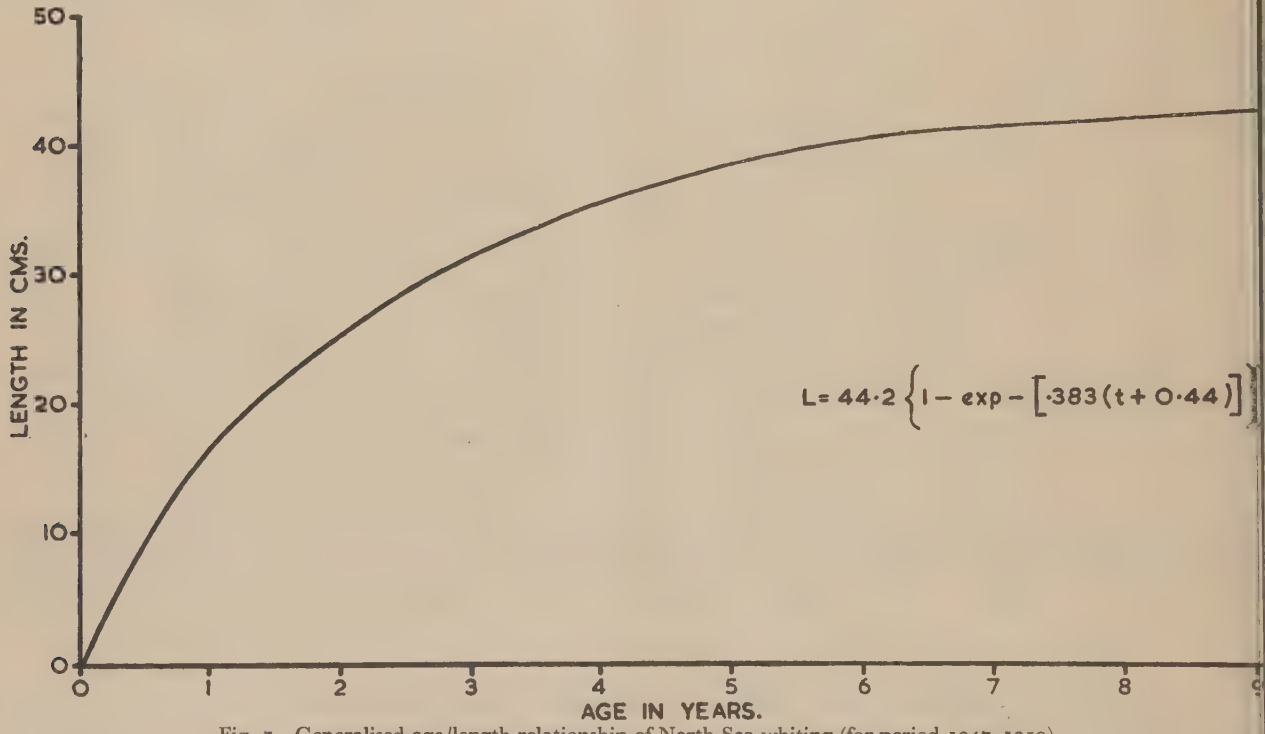

Fig. 7 Generalised age/length relationship of North Sea whiting (for period 1947–1950).

These data are compared in Table VIII with those given by earlier authors. Comparison wi Damas (1909) suggests a higher growth rate now than before the first world war. Fulton (1901) ga

TABLE VIII

Mean sizes (cm) of whiting taken from different parts of the North Sea

	Period	Age								
		1	1½	2	2½	3	3½	4	4½	5
Lat. 54°-59°N (Damas 1909) ..	Sept.		20·2		23·9		30		33·7	
Aberdeen Bay (Fulton 1901) ..	Autumn		23·7		31·3		46·9		53·4	
Gulf of Gascony (Desbrosses 1948)	Winter	18·5		25·2		34		43·3		47·6
Northern and Eastern North Sea and Moray Firth (1948-1950)	April	17		25·6		31·6		35·6		38·3

larger sizes for Aberdeen Bay but these were not necessarily representative of the deeper North Sea basin. Desbrosses (1948) gives the mean sizes of whiting from the Gulf of Gascony and these are considerably higher than the North Sea results obtained here. Evidently, variation is wide, although these differences will not greatly affect the results set out below.

THE RELATIONSHIP BETWEEN YIELD AND MORTALITY RATE

The increase in whiting landings during the past few years has served not only to emphasise the present importance of this species, but to suggest that the reduced fishing effort since the war may have contributed to the higher sustained yield. This is shown in Table IX, giving the annual and average European landings of whiting during pre- and post-war years, as well as the comparable effort in "British trawler hours". The calculation of these latter figures requires a little explanation. In Table IX are given the annual landings by British steam trawlers as well as the number of hours fishing contributing to those landings. The estimates of total European effort, in units of "British trawler hours", are then calculated by simple proportion from the formula:

$$\frac{\text{(Total European landings)}}{\text{(British trawler landings)}} \times \text{(Hours fishing by British trawlers)}$$

TABLE IX

Showing total landings of whiting by all European countries, and by British steam trawlers: also calculation of total European effort in units of "British trawler hours".

	Whiting landings (in metric tons)		Hours fishing (in millions) by "British trawlers"		
	Total European	British Steam trawlers	British Steam trawlers	Total European	
1931	37445	20,000	2·4	4·5	
2	42,188	23,000	2·3	4·2	
3	36,265	19,000	2·6	5·0	mean 4·7
4	38,183	20,000	2·7	5·2	
5	41,959	24,000	2·6	4·5	
6	33,885	19,000	2·5	4·5	
7	30,910	14,000	2·2	4·9	
1947	45,768	15,000	1·1	3·4	
8	59,073	19,000	1·2	3·7	
9	35,692	10,000	1·1	3·9	mean 3·7
50	45,441	12,000	1·1	4·2	
1	73,446	20,000	1·1	4·0	
2	73,340	25,000	1·1	3·2	

mean 37,262

mean 55,460

This calculation can only be regarded as a best estimate in the absence of other data, but it is reasonably legitimate provided it is assumed that the distribution of British trawlers is representative of that of other European vessels, and also that discarding of whiting at sea by all other vessels is the same as that by British steam trawlers.

If this premise is accepted, it would appear from Table IX that a 21% decrease in effort has bee associated with a 49% increase in landings. It is of course possible that the post-war increase in yiel is simply the result of an increase in recruitment, but analysis of the logarithms of the second year fre quencies in Table V shows that there is no significance between the mean pre- and post-war broo strengths. In the hope of throwing more light on the question an attempt was made to determine th relationship between yield and fishing effort indirectly by the application of recent population techniques

The principle behind this approach is not new. Briefly it can be stated that once a year class ha reached an age such that an average sized fish can no longer escape through the meshes of a commercia trawl it is possible to predict its contribution in terms of weight to a fishery, provided that the followin information can be ascertained:

(1) The mortality rates due to fishing and natural causes throughout the life of the year class,

(2) The rate of increase in the weight of each individual from year to year, and

(3) The average age and size of the year class at the time of first entering the fishery.

The procedure for calculating the yield per recruit from these facts, on the assumption that bot mortality rates remain constant with age, has been described by Beverton (1953) and Parrish and Jone (1953); for reference the appropriate formula for making these calculations has been set out in Appendi III.

Since the primary requirement is to determine the relationship between yield and the fishin mortality rate, it is sufficient at first to determine values of the yield for a range of values of the latte The unknowns are (a) the natural mortality rate, (b) the age that corresponds with the 50% release siz of whiting from commercial trawls and (c) the parameters of the "Bertalanffy growth curve" (Beverto 1953). The growth parameters have been determined above (Fig. 7) and are incorporated in th equation:

$$L = 44.2(1 - e^{-.383(t+0.44)})$$

where L is the mean length of a year class aged 't' years. Assuming, then, that the weight of a whiting proportional to the cube of its length, the constants in this equation can be used directly in the yie equation (Appendix III).

$$\text{i.e., } 0{\cdot}383 = K \text{ and } -0{\cdot}44 = t_0$$

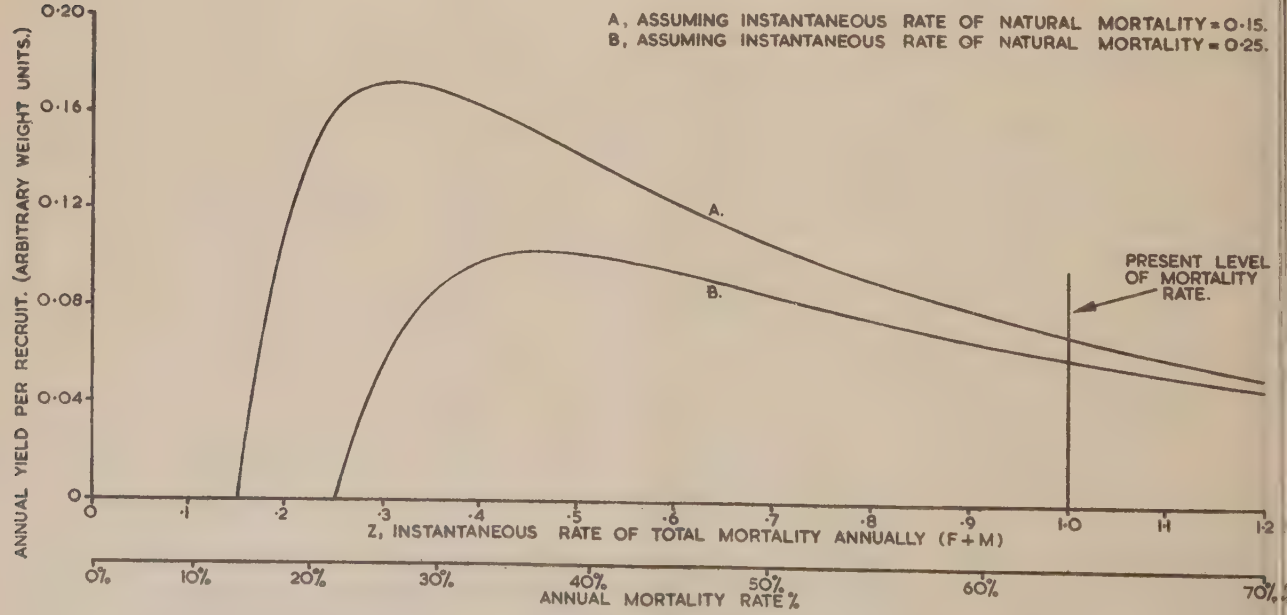

Fig. 8 Generalised relationship between yield and mortality rate in the North Sea whiting stock.

The age at first entering the fishery has been taken as that corresponding to the 50% release point of a 70 mm codend. Lucas et al (1954) have shown that this is approximately 24 cm, a length which corresponds with an age of 1·85 years; 1·85 then corresponds to the parameter $t\rho'$ in the yield equation.

The only other parameter needed to plot the yield equation is the natural mortality coefficient. Values of 0·15 and 0·25 have been assumed and used in conjunction with the other parameters determined above for calculation of the yield/mortality rate curves which are plotted in Fig. 8.

In order to complete the picture it was necessary to determine the present level of the total mortality rate in the North Sea. Samples collected by *Explorer* during the period 1946-1948 provided data on the catches per unit fishing time of various whiting broods at successive ages that could be used for this purpose; these data are shown in Table X.

TABLE X

Catches per 100 hours' fishing of different whiting year classes at successive ages, taken by *Explorer* in the North Sea.

Age \ Year Class	1942	1943	1944	1945	1946	1947	1948
0+					1,987	2,092	11,905
1+				3,201	501	1,111	2,452
2+			958	3,559	668	879	9,364
3+		296	1,494	1,036	362	1,379	
4+	220	662	321	242	100		
5+	113	56	55	37			
6+	25	12	8				
7+	2	2					
8+	2						

These numbers were converted to logarithms and estimates of the instantaneous rate of total mortality obtained for each year class separately by carrying out a regression of the log numbers on age as described by Jones (1955a). The estimates for the different year classes did not differ significantly at the 5% level and so a pooled estimate of instantaneous total mortality rate of 1·03 was computed (with 95% limits of 0·78 and 1·28), a value that agrees remarkably with that of 1·03 obtained by Parrish and Main (1950) for North Sea haddock.

Referring back to Table IX it is now possible to relate a total fishing effort of 3·7 million "British trawler hours" to the instantaneous mortality rate of 1·03, or more correctly to fishing mortality rates of 0·88 or 0·78 according to the value of natural mortality assumed. A pre-war fishing effort of 4·7 million hours should therefore be equivalent to fishing mortality rates of 1·12 and 0·99 respectively, or total mortality rates of 1·27 and 1·24. From Fig. 8 we see that a change in total mortality rate from 1·24 or 1·27 to 1·03 is equivalent to an increase in total yield of approximately $\frac{0{\cdot}6}{0{\cdot}4}$ or 1·5. From Table IX we see that the post-war increase in yield was actually equivalent to $\frac{55{,}460}{37{,}262}=1{\cdot}5$, in remarkable agreement with the theoretical figure.

While this result is rather striking it should be accepted with reservation, for a considerable quantity of whiting are rejected at sea in favour of more valuable fish and it seems highly probable that the proportion rejected before the war was greater than that rejected afterwards. If this could have been taken into account the post-war increase in yield of whiting would have been less than 1·5. It might therefore be safer to conclude that the post-war increase in whiting catches was, if anything, less than rather than equal to that expected on theoretical grounds.

This conclusion is not inconsistent with the trend in total haddock landings from the North Sea which, on average, were actually lower than those in the ten years preceding the war. There is no evidence to suggest that haddock recruitment has been consistently lower during post-war years than pre-war; in fact, the contrary is probably true, and an application of the yield equation for North Sea haddock (Parrish & Jones, 1953) suggests that the post-war haddock landings should have resembled those of the whiting in being higher than pre-war. While the apparent agreement between theory and observation in the case of whiting may simply be fortuitous, it may be concluded that the available evidence is not inconsistent with the theory that the increase in whiting landings after the war was due to the lower fishing effort.

SUMMARY

The whiting is distributed over most of the fishing grounds of the North Eastern Atlantic but of these the North Sea is much the most important in contributing more than 50% of the European landings. During the post-war years there has been an increase in these landings both in the trawl fisheries and in the growing Scottish seine net fishery. Landings from Danish waters have become particularly heavy because of the comparatively recent increase in the Danish "Industrifisk fishery".

Whiting spawn throughout the northern North Sea, principally in April and May, and eggs and larvæ are encountered all over the distribution range of the adults within the 200 m line, but mostly within the 100 m line. They tend to take to the bottom at some 60 mm in length. For their first two years of life, young whiting are to be found in the greatest numbers between latitudes 55° and 57°N.

Adult whiting are found all over the North Sea although their centre of density is no longer in the central regions but tends to be further to the north. Whether this can be regarded as evidence of a northerly migration with age, or simply as the consequence of the much higher rate of fishing that takes place in the central area, it is not possible to say.

A study of the commercial whiting statistics revealed that there had been an increase in post-war landings associated with a decrease in the total fishing effort. A theoretical relationship between fishing mortality rate and yield was derived for the whiting and it was concluded that the post-war increase in landings was such that it could reasonably have been due to the decrease in fishing effort that actually took place.

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APPENDIX I

Showing annual weights in thousands of kilos (above) and percentages (below) of adult whiting landed from European fishing grounds by all demersal fishing vessels[1]
(from *Bulletin Statistique des Pêches Maritimes*)

ear	North Sea	Kattegat Skagerak Belt Sea	Baltic Sea	Iceland	Faroe	Norwegian Sea	Rockall N. W. Scot N. Ireland	English Channel	Irish Sea Bristol Channel	W. Coast Ireland	S. Coast Ireland	Bay of Biscay	Mixed Grounds[2]
6	18,957 82·4	104 0·4	—	425 1·8	37 0·2	—	862 3·7	1,438 6·3	903 3·9	71 0·3	189 0·8	9 +	6 +
7	17,759 73·8	1,530 6·4	—	733 3·1	168 0·7	—	998 4·1	971 4·0	1,242 5·2	103 0·4	537 2·2	7 +	6 —
8	23,219 72·0	3,246 10·1	—	406 1·3	38 0·1	9 +	1,308 4·1	850 2·6	1,514 4·7	103 0·3	932 2·9	14 +	588 1·8
9	24,275 76·7	2,101 6·7	—	547 1·7	34 0·1	10 +	1,001 3·2	636 2·0	1,620 5·1	48 0·1	587 1·9	8 +	770 2·4
0	27,991 79·2	2,091 5·9	—	503 1·4	57 0·2	9 +	910 2·6	896 2·5	1,765 5·0	56 0·1	878 2·5	2 +	160 0·5
1	27,515 79·5	1,374 4·0	—	364 1·1	32 +	10 +	742 2·0	1,197 3·4	2,201 6·4	64 0·2	787 2·3	8 +	327 0·9
2	36,021 84·1	1,463 3·4	—	248 0·6	123 0·3	4 +	709 1·7	1,218 2·8	2,016 4·6	85 0·2	624 1·5	8 +	318 0·7
3	34,656 87·0	1,263 3·1	—	157 0·4	71 0·2	8 +	—	—	—	60 0·2	247 0·6	4 +	3,360 8·4
4	32,775 86·7	1,298 3·4	3 +	259 0·7	139 0·3	13 +	612 1·6	830 2·2	1,573 4·2	112 0·3	195 0·5	—	4·0 0·1
5	16,370 64·1	3,291 12·8	—	103 0·4	68 0·3	13 +	227 0·9	1,509 5·9	1,277 5·0	19 +	225 0·9	—	2,447 9·5
6	13,849 53·7	5,215 20·1	—	69 0·2	46 0·1	19 +	131 0·5	—	596 2·3	12 +	9 +	—	5,858 22·7
7	8,369 43·7	2,781 14·4	—	42 0·2	3 +	10 +	88 0·5	—	542 2·8	7 +	21 +	—	7,296 38·1
8	10,681 40·9	2,682 12·5	—	—	2 +	11 +	88 0·4	—	368 1·7	8 +	25 +	—	7,521 35·2
9	17,342 53·9	2,597 8·0	—	481 1·5	41 +	16 +	663 2·0	1,963 6·1	1,739 5·4	19 +	602 1·9	1 +	6,753 21·0
0	25,558 46·8	2,266 4·1	—	412 0·8	29 +	867 1·6	1,010 1·8	2,107 3·9	1,966 3·6	73 +	1,503 2·7	3 +	18,862 34·5
1	28,550 60·3	2,258 4·8	—	220 0·5	5 +	34 +	1,577 3·4	2,452 5·2	2,051 4·3	111 0·2	1,343 2·8	3 +	8,711 18·4
2	26,801 59·1	2,760 6·1	—	408 0·9	27 +	30 +	1,939 4·3	1,108 2·4	2,849 6·3	27 +	850 1·9	8 +	8,539 18·9
3	24,361 60·0	2,562 6·3	1 +	232 0·6	30 +	28 +	1,449 3·6	1,284 3·2	2,585 6·4	33 +	486 1·2	3,252 8·0	4,317 10·6
4	30,216 62·4	3,445 7·1	—	524 1·1	17 +	19 +	796 1·7	1,207 2·5	1,994 4·1	116 0·2	282 0·6	3,465 7·1	6,370 13·1
5	25,826 61·0	3,504 8·2	—	442 1·0	23 +	14 +	1,261 3·0	4,506 10·7	2,075 4·9	72 0·1	934 2·2	2,986 7·0	662 1·6
6	25,792 63·9	3,323 8·2	—	499 1·2	42 0·1	36 0·1	1,623 4·0	3,705 9·2	1,957 4·8	137 0·3	947 2·3	2,240 5·7	30 0·1
7	30,456 60·6	3,544 7·0	—	1,307 2·6	90 0·1	37 +	1,801 3·6	5,116 10·2	2,823 5·6	353 0·7	1,408 2·8	2,246 4·5	1,102 2·2
8	33,603 60·0	4,158 7·4	—	1,247 2·2	45 +	34 +	1,443 2·6	5,921 10·6	3,406 6·1	903 1·6	1,706 3·0	2,855 5·1	707 1·3
9	42,607 62·5	5,567 8·1	—	820 1·2	37 +	21 +	2,773 4·1	6,580 9·7	3,901 5·7	981 1·4	2,208 3·2	1,995 2·9	688 1·0

Year	North Sea	Kettegat Skagerak Belt Sea	Baltic Sea	Iceland	Faroe	Norwegian Sea	Rockall N.W. Scot N. Ireland	English Channel	Irish Sea Bristol Channel	W.Coast Ireland	S. Coast Ireland	Bay of Biscay	Mixed Ground
1930	35,845 55·2	5,144 7·9	—	1,039 1·6	174 0·3	66 0·1	3,896 6·0	5,348 8·2	4,503 6·9	704 1·1	2,671 4·1	2,971 4·6	2,52 3·
1931	37,445 53·1	6,124 8·7	—	754 1·1	184 0·3	34 +	3,415 4·8	10,438 14·8	3,954 5·6	610 0·9	4,101 5·8	1,498 2·1	1,90 2·
1932	42,188 53·4	5,272 6·7	—	652 0·8	279 0·4	35 +	5,096 6·5	11,818 15·0	3,325 4·2	801 1·0	3,427 4·3	1,169 1·5	4,89 6·
1933	36,265 46·6	8,475 10·9	—	893 1·1	335 0·4	69 0·1	5,261 6·7	10,750 13·8	3,555 4·6	2,320 3·0	4,875 6·3	2,522 3·2	2,51 3·
1934	38,183 53·4	5,211 7·3	—	1,026 1·4	541 0·8	37 0·1	3,979 5·6	10,740 15·0	3,946 5·5	1,204 1·7	4,368 6·1	2,175 3·0	10 0·
1935	41,959 56·6	6,011 8·1	3 +	1,160 1·6	777 1·0	121 0·2	1,947 2·6	9,383 12·7	4,898 6·6	1,173 1·6	3,338 4·5	2,887 3·9	41 0·
1936	33,885 49·1	7,572 11·0	—	1,115 1·6	589 0·9	53 0·1	3,099 4·5	10,123 14·7	4,056 5·9	1,195 1·7	4,077 5·9	2,466 3·6	80 1·
1937	30,910 45·2	7,688 11·3	+	1,257 1·8	438 0·6	73 0·1	3,393 5·0	10,964 16·0	3,597 5·3	1,253 1·8	4,114 6·0	1,387 2·0	3,25 4·
1938	36,592 47·0	8,521 11·0	1 +	1,092 1·4	581 0·7	81 0·1	5,219 6·7	9,764 12·6	5,683 7·3	1,295 1·7	4,179 5·4	3.778 4·9	1,00 1·
1939	24,867 41·1	12,854 21·2	132 0·2	752 1·2	102 0·2	65 +	1,750 2·9	110 0·2	1,964 3·2	107 0·2	611 1·0	2 +	17,17 28·
1940	8,712 22·6	6,061 15·7	24 +	144 0·4	288 0·7	33 +	3,508 9·1	—	2,462 6·4	104 0·2	281 0·7	—	16,92 43
1941	12,079 31·8	5,883 15·4	28 +	327 0·9	194 0·5	39 0·1	3,200 8·4	—	2,777 7·3	113 0·3	383 1·0	—	12,93 34
1942	14,172 30·2	9,697 20·7	33 +	621 1·3	258 0·6	37 +	5,851 12·5	—	4,397 9·4	172 0·4	306 0·7	—	11,3 24
1943	11,780 28·2	11,706 28·1	56 0·1	418 1·0	219 0·5	14 +	3,806 9·1	—	2,732 6·5	173 0·4	302 0·7	—	10,5 25
1944	9,406 27·2	6,159 17·8	66 0·2	243 0·7	166 0·5	24 +	3,564 10·3	—	5,271 15·3	141 0·4	273 0·8	—	9,2 26
1945	12,353 25·6	5,871 12·2	1 +	315 0·7	216 0·4	61 0·1	3,204 6·6	—	8,156 16·9	89 0·2	301 0·6	—	17,6 36
1946	36,067 46·0	7,100 9·1	29 +	951 1·2	728 0·9	83 0·1	4,891 6·2	1,408 1·8	11,297 14·4	198 0·3	732 0·9	—	14,88 19
1947	45,768 48·9	5,688 6·0	+ +	2,228 2·4	1,373 1·5	119 0·1	7,033 7·5	4,180 4·5	12,943 13·8	231 0·2	10,869 11·6	2,780 3·0	4 0
1948	59,073 60·4	3,935 4·0	+ +	3,325 3·4	1,047 1·1	55 0·1	5,052 5·2	4,044 4·1	14,987 15·3	2,745 2·8	3,210 3·3	—	4 (
1949	35,692 45·6	3,810 4·8	9 +	3,196 4·1	1,388 1·8	52 0·1	5,089 6·5	9,326 11·9	14,446 18·5	1,263 1·6	2,437 3·1	1,051 1·3	5
1950	45,441 61·2	3,196 4·3	+ +	2,240 3·0	1,746 2·4	43 0·1	4,487 6·0	4,923 6·6	7,691 10·4	212 0·3	1,989 2·7	1,019 1·4	1,2 1
1951	73,446 72·7	2,851 2·8	—	2,652 2·6	2,223 2·2	45 +	4,217 4·2	3,132 3·1	7,781 7·7	292 0·3	2,841 2·8	1,245 1·2	3 0
1952	73,340 68·5	3,846 3·6	2 +	3,114 2·9	1,632 1·5	51 +	4,579 4·3	7,455 7·0	7,809 7·3	492 0·5	2,830 2·6	1,838 1·7	
1953	62,531 62·7	2,723 2·7	3 +	3,069 3·1	1,730 1·7	53 0·1	7,104 7·1	8,517 8·5	7,622 7·6	582 0·6	3,210 3·2	2,636 2·6	

(1) These figures do not include landings of whiting by herring trawlers or vessels engaged in the Danish 'Industrifisk' fishery.

(2) Including Barents Sea, Portuguese Coast and Newfoundland.

APPENDIX II

Showing annual weights in thousands of kilos (above) and percentages (below) of adult whiting landed from the North Sea by all demersal fishing vessels[1]

(from *Bulletin Statistique des Pêches Maritimes*)

Year	Belgium	Denmark	England	France	Germany	Holland	Norway	Scotland	Sweden	All Countries
1906	349 1·9	—[2]	10,492 55·3	—	110 0·6	946 5·0	—	7,060 37·2	—	18,957
1907	266 1·5	—	9,621 54·2	—	245 1·4	931 5·2	—	6,696 37·7	—	17,759
1908	268 1·2	—	11,442 49·3	—	3,451 14·9	1,042 4·5	15 0·0	7,001 30·1	—	23,219
1909	300 1·2	9 0·0	12,399 51·2	—	4,404 18·1	1,084 4·5	19 0·0	6,060 25·0	—	24,275
1910	324 1·2	—	13,532 48·3	—	5,438 19·4	1,705 6·1	16 0·1	6,976 24·9	—	27,991
1911	287 1·0	—	12,080 43·9	—	6,667 24·2	1,774 6·4	12 0·0	6,695 24·3	—	27,515
1912	278 0·8	—	17,130 47·6	—	8,025 22·3	2,443 6·8	12 0·0	8,133 22·6	—	36,021
1913	—	+	18,903 54·5	—	2,901 8·4	2,171 6·3	4 0·0	10,677 30·8	—	34,656
1914	—	24 0·1	15,345 46·8	—	3,274 10·0	2,832 8·6	9 0·0	11,291 34·5	—	32,775
1915	—	19 0·1	7,824 47·8	—	539 3·3	2,458 15·0	8 0·0	5,522 33·7	—	16,370
1916	—	148 1·1	4,704 34·0	—	26 0·2	3,699 26·7	15 0·1	5,257 38·0	—	13,849
1917	—	34 0·4	2,804 33·5	—	635 7·6	1,947 23·3	17 0·2	2,932 35·0	—	8,369
1918	—	1 0·0	4,506 42·2	—	714 6·7	1,693 15·9	22 0·2	3,745 35·1	—	10,681
1919	—	4 0·0	9,406 54·2	—	1,730 10·0	2,278 13·1	24 0·1	3,900 22·5	—	17,342
1920	214 0·8	1 0·0	14,637 57·3	—	1,933 7·6	1,125 4·4	100 0·4	7,548 29·5	—	25,558
1921	—	4 0·0	12,775 44·7	—	5,318 18·6	1,715 6·0	90 0·3	8,648 30·3	—	28,550
1922	—	7 0·0	11,013 41·1	—	6,171 23·0	2,277 8·5	57 0·2	7,270 27·1	6 0·0	26,801
1923	—	16 0·1	11,645 47·8	—	3,340 13·7	2,320 9·5	26 0·1	7,013 28·8	1 0·0	24,361
1924	—	320 1·1	12,566 41·6	—	5,527 18·3	2,136 7·1	28 0·1	9,637 31·9	2 0·0	30,216
1925	—	178 0·7	10,008 38·8	1,677 6·5	4,386 17·0	2,069 8·0	36 0·1	7,459 28·9	13 0·0	25,826
1926	—	56 0·2	10,270 39·8	1,636 6·3	3,902 15·1	2,437 9·4	13 0·1	7,396 28·7	82 0·3	25,792
1927	—	102 0·3	10,780 35·4	3,103 10·2	4,609 15·1	2,498 8·2	13 0·0	9,349 30·7	2 0·0	30,456
1928	36 0·1	153 0·4	11,348 33·8	5,795 17·2	4,498 13·4	2,303 6·8	18 +	9,449 28·1	3 +	33,603
1929	1,719 4·0	164 0·3	13,611 31·9	7,412 17·3	5,174 12·1	3,050 7·1	37 +	11,413 26·7	26 +	42,607

Year	Belgium	Denmark	England	France	Germany	Holland	Norway	Scotland	Sweden	All Countri
1930	1,681 4·5	81 0·2	10,219 28·5	5,640 15·7	4,699 13·1	2,117 5·9	43 0·1	11,346 31·6	19 +	35,845
1931	1,348 3·5	59 0·1	10,534 28·1	5,825 15·5	5,235 13·9	2,007 5·3	46 0·1	12,342 32·9	49 0·1	37,445
1932	1,613 3·8	142 0·3	11,659 27·6	6,467 15·3	4,739 11·3	1,944 4·6	41 0·1	15,455 36·6	128 0·3	42,188
1933	1,247 3·4	21 +	9,528 26·2	7,150 19·7	4,325 11·9	1,033 2·8	35 0·1	12,600 34·7	326 0·8	36,265
1934	1,267 3·3	4 +	9,100 23·8	6,501 17·0	4,064 10·6	1,498 3·9	52 0·1	14,600 38·2	1,097 2·8	38,183
1935	1,383 3·2	9 +	9,161 21·8	5,930 14·1	4,042 9·6	1,683 4·0	56 0·1	18,424 43·9	1,271 3·0	41,959
1936	1,727 5·0	29 +	6,582 19·4	3,235 9·5	3,607 10·6	2,221 6·5	67 0·2	15,156 44·7	1,261 3·7	33,885
1937	1,715 5·5	34 0·1	5,894 19·0	5,386 17·4	3,147 10·1	2,133 6·9	59 0·2	11,173 36·1	1,365 4·4	30,910
1938	1,898 5·1	3 +	6,779 18·5	6,016 16·4	3,349 9·1	2,863 7·8	59 0·1	14,019 38·3	1,606 4·3	36,592
1939	1,543	3	—	—	3,437	2,810	102	15,931	1,041	24,867
1940	—	30	—	—	276	2,195	33	6,115	63	8,712
1941	118	36	—	—	126	3,897	51	7,975	—	12,079
1942	206	16	—	—	58	2,580	68	11,450	—	14,172
1943	162	11	—	—	38	1,525	177	10,029	—	11,780
1944	25	—	—	—	24	190	109	9,058	—	9,406
1945	982	+	—	—	—	2,497	90	9,117	167	12,353
1946	3,540	1	5,397	—	2,940	5,656	52	18,094	387	36,067
1947	2,932 6·4	1 +	4,492 9·8	6,164 13·5	2,478 5·4	6,346 13·9	131 0·3	22,574 49·3	650 1·4	45,768
1948	2,773 4·7	15 +	3,944 6·7	17,183 29·1	2,810 4·7	3,518 6·0	48 0·1	27,357 46·3	1,425 2·4	59,073
1949	1,977 5·5	11 +	2,986 8·4	10,187 28·5	1,591 4·5	3,371 9·4	36 0·1	14,227 39·9	1.306 3·7	35,692
1950	2,286 5·0	10 +	4,362 9·6	15,430 34·0	988 2·2	5,014 11·0	34 0·1	16,260 35·8	1,057 2·3	45,441
1951	3,063 4·2	12 0·0	6,443 8·8	21,538 29·3	749 1·0	6,860 9·3	14 0·0	33,631 45·8	1,136 1·5	73,446
1952	2,255 3·1	115 0·2	5,882 8·0	14,169 19·3	640 0·9	7,962 10·9	19 0·0	40,985 55·9	1,313 1·8	73,340
1953	1,595 2·6	81 0·1	4,565 7·3	14,369 23·0	772 1·2	6,638 10·6	40 0·1	33,095 52·9	1,376 2·2	62,531

(1) These figures do not include landings of whiting by herring trawlers or vessels engaged in the Danish 'Industrifisk' fishery.
(2) Landings not given.

APPENDIX III

Formula for calculating the equilibrium relationship between mortality rate and yield per recruit.

Let Y = Equilibrium Yield per recruit of age $t\rho'$ years.

ρ' = Average age at which a year class enters the fishery.

W_∞ = Asymptote towards which the mean weight of a brood is tending.

Z = Instantaneous rate of mortality due to fishing plus natural causes—assumed constant with age.

F&M = Instantaneous rates of mortality due to fishing and natural causes respectively so that $F+M=Z$.

K & t_o = Growth constants.

Then
$$Y = W_\infty F\left\{\frac{1}{Z} - \frac{3e^{-K(t\rho' - t_o)}}{Z+K} + \frac{3e^{-2K(t\rho' - t_o)}}{Z+2K} - \frac{e^{-3K(t\rho' - t_o)}}{Z+3K}\right\}$$

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